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ABSTRACT

Part of an Office of Education three-year project on metric education, the position paper is intended to alert and prepare teachers, curriculum developers, and administrators in vocational, technical, and adult education to the change over to the metric system. The five chapters cover issues in metric education, what the metric system is all about, the impact metrication will have on vocational and technical education, the implications of metric instruction for adult basic education, and curriculum and instructional strategies. Each of the chapters is organized into four parts. The first part is a one-page overview which highlights the main points of the chapter. The second consists of some questions and answers which reflect the fears and concerns of teachers, administrators, and students. The third part contains in-depth coverage of the subject, and the fourth is a brief list of references for those who may wish to read further. (Author/EA)

# METRIC EDUCATION

## A Position Paper for Vocational, Technical and Adult Education

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## FOREWORD

Changeover to the metric system is underway. Large corporations are already using metric measurement to compete on the world market. Although the metric system has not been the primary measurement system in the United States, it has been legally permitted since 1866. It has been used in various segments of the industrial and scientific communities for years. Federal legislation to facilitate an orderly transition is pending. As businesses and industries make this transition, employees will need competency in application of the metric system to tasks on their jobs.

The Center for Vocational Education has maintained a focus on career planning and preparation and recognizes the critical importance of metric skills in tomorrow's jobs. The U.S. Office of Education has shown foresight in preparing to intercept the emerging need with instructional materials for use in vocational, technical, and adult education. This position paper was prepared as part of a three-year project sponsored by USOE and conducted by The Center. It is a companion to *Metric Education: An Annotated Bibliography for Vocational, Technical and Adult Education* which provides access to currently available resources. Other products of the effort will include instructional packages for use in programs in all fifteen occupational clusters and in adult basic education, an implementation guide, and an in-service education program.

Recognition is given to the scholarly effort of Gloria S. Cooper, Joel H. Magisos, Edward F. Hauck, and Dwayne E. Channell, Center staff members on the project, who authored the paper. Special thanks are extended to Mary V. Marks, Chief of the Curriculum Development Branch, U.S. Office of Education and to Myrna G. Hugi, Program Specialist, Division of Adult Education, USOE, for their assistance during the development of this document. Appreciation is expressed to John L. Feirer, director of the Center for Metric Education at Western Michigan University; Richard A. Dieffenderfer, Research Specialist at The Center; John Barton, Research Specialist at The Center; and Mae Huang, Graduate Research Associate at The Center, for their critical review of earlier drafts of the paper. Comments and suggestions from the field are welcome.

Robert E. Taylor
Director
The Center for Vocational Education

## INTRODUCTION

This paper is addressed to teachers, curriculum developers, and administrators in vocational, technical and adult education, all of whom will soon be involved in the implementation of metric instruction. It is intended to make educators aware of the kinds of changes they may anticipate in their program areas and prepare them to meet the challenge in constructive and positive ways.

In addition to serving as a position paper, it can be used as an in-service tool, a handy reference on the impact of metrication, or as the teacher's first step in learning about metric and the metric changeover.

The five chapters cover issues in metric education, what the metric system is all about, the impact metrication will have on vocational and technical education, the implications of metric instruction for adult basic education, and curriculum and instructional strategies. The reader is invited to browse through the chapters as he or she develops a need to know. Vocational-technical educators can skip Chapter III and ABE teachers can ignore Chapter II without detriment.

Each of the chapters is organized into four parts. The first part is a one page overview which highlights the main points of the chapter. The second consists of some questions and answers which reflect the fears and concerns of teachers, administrators and students. The third part contains in-depth coverage of the subject, and the fourth is a brief list of references for those who may wish to read further.

Concerns about transition to the metric system spring from a lack of information. People with exposure to metric terms know that the metric system is easy to learn. The problem is a nonproblem.

## CHAPTER I

## ISSUES IN METRIC EDUCATION

When we consider the development and utilization of metric instructional materials for vocational, technical and adult education, it is useful to consider several different issues. These issues concern the metric system (Is it difficult?), the students (Are they ready?), teaching metrics (How will we go about it?), and metrication (When will it come?).

### The Metric System: Is It Difficult?

Clearly, the small set of terms and values that characterize metric measurement pose no serious learning problem for those who already possess measurement skills. The teaching and learning of metric terms for this audience is equivalent to teaching and learning a second language. What is required is learning the rules for ordering metric bases and their prefixes in sentences. It will take a little time, not very much, namely weeks not years, to learn the new rules and put them into American English. For example, a litre is not a quart plus another unit, but is itself a discrete unit. Learners will internalize the appropriate meanings of the terms and will be able to understand and use them correctly in their speech and writing.

Perhaps the most difficult part of learning the metric language is choosing a personal referent against which to compare, estimate, and verify metric unit sizes. Each of us has a different referent which has meaning for us. Students must be given the opportunity and the time to look for, test, select and internalize their own contextual clues. For some it may be a body part, for others it may be an external object. Clues will be different for each person but will trigger the same meanings.

We all know that you don't learn to ride a bike or use a typewriter by listening to a lecture on the subject or reading about it in the library. So far, the best we've been able to manage for developing the skills of balancing on a moving bike is to get on the bike and practice. The only way to develop the appropriate motor cues is by doing it. The finger dexterity and eye-hand coordination required in typing are acquired by using the typewriter and training for motor patterns that produce typed pages. Notice that reference is made to pages, not words or sentences. Learning to type a single word in isolation will not teach anyone to type sentences, but may be a precursor to such learning. Typing a sentence in isolation will not teach the student to type paragraphs but is a prerequisite. It is the typing of words and sentences in a larger context, and the patterned repetitions of such activity, that will provide the eye-hand coordination needed for production typing. In the same way, metric mastery will occur by providing enough time to handle and use metric sized objects, tools and equipment.

We may anticipate learner difficulties in appropriately using metric terms. The ability to estimate is required. The student will also need to develop skill in selecting the appropriate size unit

with which to measure; for example, measuring carpeting in square metres not square centimetres, or measuring road distances in kilometres not centimetres.

A second possible area of difficulty may be in associating metric prefixes with the place-value structure of the base ten system. It may take additional effort to learn to multiply or divide by powers of ten when metric equivalencie. are necessary.

The teaching of metric units is a wonderful opportunity to teach for a skill which receives too little attention in schools; the ability to estimate. Much of the metric learning activities should be concerned with estimating and verifying. In addition, the student should develop the ability to make educated guesses and develop confidence in this ability. Boyd Henry of the National Council of Teachers of Mathematics' metric implementation sub-committee emphasizes this point. So does Max Bell, a math educator at the University of Chicago.

## The Students: Are They Ready?

We can assume that most vocational and technical education students (grade 10-14) already have measurement skills since it is part of the curriculum content of grades K-8. However, we recognize that some of these students may not have mastered all of the basic measurement skills necessary for success in a vocational program.

For students with measurement skills, metric terms are easily learnable IF, (that is an important word), IF they *want* to learn them. Why will students want to learn a new vocabulary? Because the teacher said so? Some students will. Because it's necessary in order to function in the real world? In the stores? On the job? In the kitchen? MOST students will. As soon as learners *need* to know metric terms then they *will* learn them. The variable here is the *NEED* to know.

Vocational and technical education students who have not acquired appropriate basic measurement skills can be provided the opportunity to learn them through the vehicle of the metric system. Concrete learning experiences, simple learning steps, and opportunities to perform successfully give these students a second chance to remedy deficits.

Regular vocational and technical education students will be able to exit from programs equipped with entry level skills which include metric measurement. These skills will provide a job market advantage both for acquiring a job and for mobility on the job. These persons will probably be called upon to help with metrication activities within businesses because they know the metric system of measurement.

Adult basic education (ABE) learners are another type of student for whom we cannot assume the mastery of measurement skills. The characteristics of these learners are unique enough to warrant special attention. Adult basic education learners do not have the motivation to learn metric terms in an environment which is not yet metric. They focus on learning tasks geared to immediate and pressing needs. Further, they expect to learn what they need in a short period of time. This haste coupled with anxiety about their own ability will make it difficult for them to accept the metric system and the need to learn it until it affects their lives and their jobs. Even so, we will need to have instructional materials ready for the time when needing to know will be acute.

## Teaching Metrics: How Will We Go About It?

Vocational and technical education teachers have traditionally treated learners as practitioners and have been accustomed to specifying hands-on experiences for learners. When teachers are shown that learning to use metric values for measurement is sensible and useful in association with measuring devices, teachers will avoid lecturing about and engage in practicing with metric measurement. Such a strategy is compatible with teachers' intuitions concerning how their students learn.

Some interesting research on low achievers will have implications for some vocational and technical education students and most adult basic education students. This research indicates that persons will perform in a manner consistent with previous reinforcement patterns. Self-perceived ability, based on previous task performance, defines later task performance (Kaufman, 1963), (Feather, 1965). Individuals and groups with low self-esteem are less likely to achieve difficult goals they have set for themselves than individuals with high self-esteem (Korman, 1968). Groups that have failed in the past develop their goals in ways that increase the likelihood of their failing again (Zander, Forward, and Albert, 1969). The individual who has had a long series of frustrations behaves in ways that are (a) persistent beyond degree of reward, (b) not alterable by punishment, (c) nongoal oriented, and (d) not affected by consequences or by the anticipation of the same (Maier, 1949). These findings have serious implications for the instructional materials and teaching methods used. These are discussed in Chapter IV.

As teachers, it is our job to bring the metric system to our students and to prepare them to understand and use the units they will encounter from day to day. Not everyone needs a complete knowledge of the metric system. In fact, most need to know only enough to function efficiently on the job and as consumers. Our major task as teachers, then, is to give our students experiences with those parts of the metric system which are relevent to them. The simple, logical structure of the metric system makes it an easy system for them to learn.

## Metrication: When Will It Come?

Metrication in everyday life will emerge from committed groups working together. Educators alone are certainly not going to cause America to go metric. Metrication relates directly to measuring events in the waking and working worlds of people. It will be the internal dissonance created by trying to shop in a metricated store, trying to work in a metricated business, trying to cook from a metricated cookbook, trying to understand the metric weather report, and so on, that will cause people to metricate. If metric skills are not useable anywhere except in the classroom they will not be learned or retained.

All the industrialized nations of the world have either implemented the metric system or have committed themselves to the changeover. As the only exception, the United States is in an unfavorable trade position with other nations. Large industries in this country who depend on foreign markets and who provide jobs at home have organized themselves informally to support metrication in this country. Metric conversion will eventually impact on every segment of our economy, starting with the machinery, parts and materials sector. However, when a large manufacturing industry metricates, it directly affects its suppliers and consumers, as well as the maintenance and repairs industries associated with it.

As business, industry, and government metricate, education can begin its job. The best we can do at the moment is anticipate this event, prepare our teachers by convincing them of the inevitability of metrication, and they will convince their students.

## Conclusion

If we all do our jobs well, the domain of metric education should cease to exist as a special area of concern. We are responding to the start-up needs in programs that will require metrication. Once implemented, metric will be taught within the context of measurement. It will be learned as a primary system and customary will be taught as the secondary system.

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## CHAPTER II

## THE METRIC SYSTEM

### Overview

People use measures all the time. They read watches, check their speedometers, put a teaspoon of sugar in their coffee, listen to the weather report, drink a glass of water, count calories, and change their money.

The METRIC system of measurement (metre-litre-kilogram) will be replacing the CUSTOMARY system of measurement (foot-quart-pound) for most things. Some of our industries have been using the metric system for a long time. Other industries want to compete for foreign markets and must go metric to do so. Those industries that can expand their markets will provide more employment for Americans. This pressure for change will affect all of us as customers, employers, employees, students, teachers, and in all the many roles in which we engage.

The metric system is not alien to us. Our currency is based on the decimal system. We were one of the first countries in the world to relate money values by tens. We can all count pennies, dimes, and dollars. We already buy 35 millimetre film. Some people smoke cigarettes that are 100 millimetres long. Marc Spitz swam the 500 metres event. Other athletes ran 1500 metres. Skis are made in centimetre sizes. Many medicines are measured in grams.

Not all the units with which we measure will change as we go metric. Time and money will be counted in the same way. We will still use watts, volts, amperes and hertz for electrical units. We will continue to look for the lumens of light marked on light bulbs or their wrappers.

A very few words have to be learned for everyday use. The milli*metre*, centi*metre*, *metre*, and kilo*metre* describe length and distance. The milli*litre* and *litre* measure capacity or volume. *Gram*, kilo*gram* and tonne are used for mass. Degree Celsius measures temperature.

The impact on vocational and technical education will vary. For those who will enter sales and office positions the conversion to the metric system will require very little specialized training. What is needed as a consumer will be sufficient. Others, such as machinists, mechanics, and draftsmen will be working with metric tools such as wrenches, dies and taps. These are different in size from customary units and will require additional training to learn.

The metric system is simple, logical and easy to understand. Learning it is not difficult.

## Concerns of Teachers and Administrators

Administrators, teachers and their students have anxiety about the metric system. Some of these are addressed in this section.

### Why should we adopt a FOREIGN measurement system?

First of all, the metric system is an INTERNATIONAL system in use throughout most of the world. We already use many metric measures in our everyday lives. Since the metric system is based on decimals, we can multiply and divide by powers of ten. Our money is a decimal system. The measurement system we now use is not organized in a logical manner. It is difficult to learn and the units are neither easy nor logical to convert. For example, substract 3/4 of a yard from 3 yards, 5 inches.

Our measurement system isolates us from the rest of the world. We are the only industrialized nation not using the metric system. When we convert we will be able to import and export goods easily, since everyone will share the same measures.

At present, we use two measuring systems. Students must learn customary measurement for everyday use and the metric system for technical and scientific use. When we convert everyone will use the metric system for all uses.

### Are we hopping on another bandwagon labelled "metric education"?

Metrication is here. It is not a matter of IF, it is a matter of WHEN. The large industries in this country have been supporting conversion to the metric system for many years. Many of them have already converted. Legislation to enable the conversion is just a matter of time. We most certainly will have converted within the next ten years. In 1968, the National Bureau of Standards conducted a study of the impact of metrication on all aspects of our economy. Conversion to the metric system was recommended in the report.

As educators, it is our job to prepare students for the world in which they are going to function as employees and consumers. It will be a metric world.

### I'm a vocational teacher. Why should I teach metric? Why can't the regular math teacher do it?

Metric is everybody's business. As a vocational educator you know that an important part of your subject matter deals with measurement and the proper use of measurement tools. Your students will need to know the metric system to use these tools for job entry. You are concerned with teaching the practical uses of tools. Who is better equipped than you are to teach the vocational applications of the metric system? The math teacher can do it, but he or she may not be able to apply the jobs for which your students are preparing.

## The Case for Changing to the Metric System

Measurement plays an important role in all of our lives. We are all clock-watchers, weight-watchers, and money-watchers. We are all conscious of the weather and of the speed at which we

travel down the highway. We measure our food and size our clothing. The list could go on. The point is that none of us can escape measurement in some form or other. It is immediate and relevant to us all.

We presently have a system of measurement which, for most of us, has worked quite well. So why should we switch to a "foreign" system of units? Why have government agencies and manufacturing firms recommended that we change to the International Metric System? The United States and a few small, non-industrialized nations are islands in a metric world. This negatively influences our economy. Parts and materials manufactured in the United States do not meet the specifications of metric countries. To compete in foreign markets, manufacturers must go metric. This change will allow businesses to expand their markets and provide for more employment. The results will affect customers, employers, employees, students, and teachers. The change to the metric system by the manufacturing community will continue to take place regardless of national plans and policies.

Besides the economic factors, there are other advantages to adopting the metric system over our present system. Our traditional system of measurement was developed over the years as a hodgepodge of weights and measures. An inch was originally defined as the length of three barleycorns, round and dry, when laid together. A yard was the distance between the end of someone's outstretched arm and their chin. Although these units are standardized today, they are not related to each other in any systematic manner. We have twelve inches in a foot, three feet in a yard, and 1,760 yards or 5,280 feet in a mile. The "ounce" is used as a unit of weight as well as a unit of liquid capacity but the two units have no practical relationship. These unsystematic relationships create calculational problems when conversion from one unit to another is required.

## The Simple Beauty of the Metric System

The metric system is a logically developed system with scientifically defined and controlled standards. There are only seven units upon which all other measurements are based. These base units (e.g., metre, litre, kilogram, etc.), signified by simple symbols, are shown in Table 1.

Table 1

METRIC BASE UNITS AND THEIR SYMBOLS

| Quantity | Unit | Symbol |
|---|---|---|
| length | metre | m |
| capacity | litre | $\ell$ |
| mass | kilogram | kg |
| temperature | degree Celsius | °C |
| time | second | s |
| electric current | ampere | A |
| matter | mole | mol |

The metric system capitalizes upon the decimal number system by relating like units through some factor of ten. The metre, the metric base unit of length, contains 10 decimetres, 100 centimetres, or 1,000 millimetres. A kilometre is 1,000 metres. Similar relationships hold for the litre, a unit of capacity, and the kilogram, a unit of mass. Conversion between metric units is usually a matter of moving a decimal place or adding some zeros; similar to the way we change dollars into cents. This is shown in Table 2. Compare changing 5.25 metres into 525 centimetres with changing 3 5/8 yards into inches and you will appreciate the relative simplicity of the metric system.

Table 2

THE METRIC PREFIXES, THEIR MEANINGS, AND THEIR SYMBOLS

| Prefix | Meaning | Symbol |
|---|---|---|
| kilo- | 1,000 | k |
| hecto- | 100 | h |
| deka- | 10 | da |
| (unit) | 1 | |
| deci- | 0.1 | d |
| centi- | 0.01 | c |
| milli- | 0.001 | m |

Not all of the multiples and submultiples of the base units will be in common usage; therefore, students will not need to develop a complete contextual reference to all possible terms. Those that will be most commonly used, shown in Table 3, will require extra attention and more practice.

Table 3

THE COMMONLY USED MULTIPLE AND SUBMULTIPLE UNITS AND THEIR SYMBOLS

| Base | Multiple or Submultiple | Symbol |
|---|---|---|
| metre | kilometre | km |
| | centimetre | cm |
| | millimetre | mm |
| litre | millilitre | ml |
| kilogram | tonne | t |
| | gram | g |

In special technical fields certain usage of derived terms and their symbol or formula will be important. Some of the commonly used derived units are given in Table 4.

Table 4

THE COMMONLY USED DERIVED UNITS
AND THEIR SYMBOLS OR FORMULA

| Quantity | Derived Unit | Symbol (or) Formula |
|---|---|---|
| area | hectare | ha |
| | square metre | $m^2$ |
| | square centimetre | $cm^2$ |
| volume | cubic metre | $m^3$ |
| | cubic centimetre | $cm^3$ |
| speed | kilometre per hour | km/h |
| pressure | pascal | Pa |
| | kilopascal | kPa |
| energy, heat | joule | J |
| | kilojoule | kJ |
| power | watt | W |
| | kilowatt | kW |
| electrical power consumption | kilowatt-hour | kW·h |

The internal consistency of the metric system and its relationship to natural phenomena (e.g., 0° Celsius is freezing, 100°C is boiling) would make it a persuasive choice even if most of the world wasn't already using it. If presented on its own merits and not taught in relationship to the confusing customary system, it should be easily learned.

## Implications of Metrication

Despite apparent advantages of the metric system over our traditional system, debates over the use of the metric system in the United States have been going on for over 150 years. The first systematic consideration of the metric system by the United States Government was made by John Quincy Adams in 1821. In 1866, Congress passed a bill legalizing the use of metric weights and measures in the United States. The bill did not make the metric system compulsory but permitted its use. From that time until the present, advocates of the metric system have pushed for legislation to make the metric system the only legally recognized system in the United States. With the

development of the International Metric System by the General Conference of Weights and Measures and the recent adoption of this system by Great Britain and Canada, it is inevitable that the United States will soon pass legislation requiring the gradual changeover to the use of metric units in all transactions.

The major implication of this conversion to everyday citizens is in the use of new words for describing and communicating measurements. However, the words and concepts are not completely new to any of us. As was mentioned previously, the metric system is based upon the decimal number system, as is our system of money. We presently buy some articles which use metric units. Many of our present units will remain unchanged after the conversion. The units of time, money, and electricity are the same in both systems. Thus, very few new words have to be learned for everyday use. For those words that are new, the logical relationship between the units and the decimal nature of the prefixes will make their learning an easy task. We will soon hear the weather announcer report temperatures in degrees Celsius. We will buy milk by the litre, use recipes calling for millilitres of liquid, read traffic signs in kilometres, measure room dimensions in metres, and buy meat by the kilogram. However, tradition may dictate that some measurements and dimensions not change to metric units. Football fields may not change in length and familiar sayings such as "a miss is as good as a mile" will not change until replaced by some new saying.

An additional implication of the changeover is that students will no longer be faced with learning two measurement systems—one for scientific applications and one for everyday measurements. Time spent on the teaching of fractions can be greatly reduced and the reduced use of fractions for complex computations and conversions will eliminate many of the chances for making calculational errors, thus increasing the confidence of our students.

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## CHAPTER III

## VOCATIONAL-TECHNICAL CURRICULUM AND METRICATION

### Overview

Vocational-technical educators are constantly changing their courses, shops, and labs to reflect changing technology, practices, and personnel needs in business and industry. Students in all occupational areas learn to use new technical language. They learn measurement units and terms they have not used before such as ampere, BTU, calorie, grain, micron, millilitre, No. 2 can, pica, pitch, psi, roentgen, and thousandths of an inch. Thus, both teachers and students are prepared to deal with change. The metric changeover in the U.S. probably will take place over a period of ten years.

Vocational and technical education is measurement sensitive. That is, students need to use measurement units, terms, and tools in their work. Conversion to the metric system will affect many occupational areas.

Changeover to the metric system will provide many opportunities for prepared vocational students to demonstrate their competence on the job, to make conversion in the labs and shops, and to assist others in metric conversion of the school, home, community, and business and industry.

### Concerns of Teachers and Administrators

Must we learn the history of the metric system, write definitions and memorize formulas?

No. Learning about the history of the metric system is not necessary to learn to use metric units. There is a difference between learning about something, and learning how to do it on the job and in daily life. Students should learn what the metric units are, what sizes they represent, when to use them, and the relationships between the units. Experienced vocational and technical education teachers will prepare useful instructional materials. The materials will be reviewed by people who know the occupations. Then they will be tried in classes and revised.

How can I find time to teach metric measurement when there is already much to learn?

Metric education may take some additional time but not much since metric content can be included in regular course activities. Student materials will be supplied so that some content can be learned through in-class self-study or outside assignments.

Students can be involved in the process of changing over the school and community to the metric system. In one British secondary school, students were vitally involved in metric conversion

activities in their own shops and labs. They worked with other school departments, and with a nearby primary school. Students in engineering, drafting, and machine shops made up sets of "metric" drills and bits from equivalent bits in inch sets, and designed and machine lathe conversion parts. They cast, machined, and fitted new dials to lathes and to the scales of the home economics department. Home economics students converted recipe books to metric measures. Commercial students typed materials for home economics and machine technology conversions. Metric education learning materials, developed for use at school, were reproduced and shared with adults in the community. Local industries assisted the school in solving technical problems and in the process identified and solved some of their own conversion problems. What began as an attempt to solve the problem of making the change without much money proved to be more profitable and of greater educational value than envisioned.

How can I teach the metric system? I'm not a math teacher and some of my students are not very good at math.

Most teachers and students will need to learn only that part of the metric system which applies to their program areas. The mathematics skills won't change; only the units of measure will change.

Formulas for converting between customary and metric measurement units generally will not be used. When using metric tools, equipment, and specifications, mathematical conversion is not necessary. Conversion tables will be used to convert between the measurement systems.

How can I teach the metric system when my teaching materials and equipment are not metric?

Only basic inexpensive tools such as metric rules, tapes, scales, and containers are needed to teach the basics of the metric system. Many household, classroom, laboratory and shop devices and tools are already metric while others can be converted. Inexpensive conversion kits are available to convert expensive lab and shop equipment to metrics. In shops and labs, it is recommended that one or two work stations be converted to metric tools and equipment at first. When new machines are purchased they should have metric capability. Conversion for school settings and industries will be gradual and guided by the "rule of reason." No one will expect the impossible! It would be a mistake to make a complete changeover too far in advance of students' needs.

What if the community or the industry does not "go metric"?

The United States is converting to the metric system. It will be the major measurement system in use—not the only measurement system. Industry is leading metric conversion and state and national governments are helping by preparing citizens, coordinating changes, and standardizing weights, measures, and product standards. All areas of life in the community and jobs in business and industry will be affected.

Shouldn't I wait for metric standards in my program area before I introduce metric measurement in my courses?

No. Students should know the basic metric units and be able to apply them in their field. This will make it easier for them to make the conversion when it is needed. Students should know

what product standards might change, how they might change, when they might change, and how rapidly their field is changing to metric measurement.

Why do some people worry about learning the metric system?

The U.S. Metric Study found that people who knew least about the metric system were the most concerned while those who knew some metric units were the least worried.

The "think metric" approach and the metrication of business and industry will eliminate most problems. Students and teachers will have experiences with metric units and common physical objects before they deal with the units and terms as abstractions. By using metric measuring tools, conversion between the systems will not usually be necessary. When conversion between the systems is required, conversion tables and charts can be used and the use of formulas and mathematical operations minimized. Experiences with metric design and production in U.S. and British industries has shown that the use of metric units simplifies mathematics and reduces errors.

## Changes in Occupations

The great variety of occupations, differences in the use of measurement, and undefined product and engineering standards make it difficult to predict changes in each occupational area. For some, we will have to wait and find out.

There is a common core of information fundamental to understanding and using the metric system. It includes the basic metric units from which other units are derived, and the units and terms which people will often encounter in daily life and on the job. The ability to use certain metric terms, symbols, base units, and derived units for length, area, volume, mass, temperature, speed, energy, and pressure will be required in many entry-level jobs. Content will be related to appropriate occupational and daily life activities. Instructional materials will be prepared and packaged as modules. Students will begin with the basic core program. If they can demonstrate they have already mastered the core information, they will begin occupationally-focused modules.

Some of the expected changes in each of fifteen occupational clusters are discussed below. It is important to remember that most changes will occur gradually and can be taken in stride.

### Agriculture and Agribusiness

A wide variety of measurements and calculations are used in agriculture and agribusiness. Because of this, and the fact that markets (such as Great Britain, Canada, Australia, and Japan) will be reporting agricultural statistics in metric units within the next two or three years, it is important to begin metric instruction soon. The basic core metric program will meet many needs, however many specialized units and calculations are also needed.

Measurement units will change for land, construction and maintenance of equipment and buildings, crops, livestock, dairy products, seed, feed, pesticides and herbicides, fertilizer, container and storage capacity, woodlot operations, irrigation and delivery capacity of sources and pumps, temperature, precipitation and/or irrigation levels, and energy, work, and power. The farm operator

will find that commodities will probably be reported and marketed in metric tonnes (1000 kg) or kilograms instead of bushels. Livestock will be marketed by kilograms instead of pounds. Milk will be sold in litres and kilolitres and not by quarts, gallons, or pounds. As farm equipment or construction fasteners change to metric, farmers will need to buy a set of metric tools.

New sets of tables will be needed for calculations of weight crops or commodities per volume, number of seeds per kilogram and planting rates, precipitation and irrigation tables, applications of fertilizer and pesticides, purchases of construction materials, number of shrubs or plants per hectare, approximate number of items per metric container for larger produce, and marketable lumber in woodlots. Farm suppliers and government agencies can be counted on to supply many of these tables free or at low cost as they are needed and available. Agricultural supplies and service workers can be a key link in helping farm operators use the metric system.

Business and Office

Business and office workers use the language and symbols of measurement more than they make measurements. In placing orders, billing customers, and typing or preparing correspondence they will use metric units. Business and office students need to learn to say and spell the names of the units and terms, write the symbols, and use proper SI metric notation. In addition, they need to be able to spot when the unit has been used inappropriately—for example, if kilolitre is used to describe distance instead of kilometre, or a person orders or is billed for 500 kilograms of chocolate (half a metric tonne) instead of 500 grams (about a pound). Stenographic notation is already available for common metric units. Paper sizes and weights, will change. Margins will be stated in millimetres, and graphic layouts will change to centimetres and millimetres. Postal rate calculations will be based on grams. Most physical changes can be taken in stride.

Communication and Media

Electrical and electronic technologies are already using the electrodynamic terms and units which were adopted in the International System of Units such as ampere, watt, volt, hertz, coulomb, and candela. They will need to learn to use common metric units for length, area, weight/mass, and temperature.

Drafting occupations are being affected early in the metrication process. Experiences in drafting rooms in U.S. industry and in foreign countries show that the changes are not expensive, students and workers adjust readily, and find it easier to work in metric units and scales. Direct measurement on drawings will change to millimetres instead of feet and inches. All linear dimensions will be shown in millimetres with surface finishes in micrometers. Drafting students will need ready references at hand for the many metric units and terms used by designers, and they will need experience in using the metric drawing scales. Many product engineering standards will change including screw threads and fasteners, gears, drill and tap sizes, materials specifications, and fit and tolerance standards. International Standards Organization (ISO) fit and tolerance standards will be used. Drafting rooms will begin to see and deal with some European first-angle projections in the future. Metric drawings will be identified with a special symbol and each drawing will be labeled to show the projection method used. Drawings developed in the United States will continue to use third-angle projections.

## Fine Arts and Humanities

Design occupations in fashions, environment, architecture, industrial facilities and products, and urban planning will be affected early in the process. Writing, editing, and related occupations are being affected.

Design length dimensions will generally be expressed in centimetres and metres, and distance in kilometres, while direct measurement on drawings will be in millimetres. New standards will appear in metric units for dimensions of facilities and products in relation to human and animal dimensions. Some will simply translate present inch standards or round metric measures to convenient whole numbers, while others will change significantly. The trend will be to simplify and reduce the number of variations in sizes. Design students who can work creatively and comfortably in metrics may have a job-placement advantage over those who cannot, during the next two to ten years—as will writers and editors. Other occupations in Fine Arts and Humanities such as dance, drama, and music may find the changeover less demanding and more gradual. Changes in technical theatre and design occupations and crafts occupations will follow the lead of related consumer, and trade and industry changes.

## Construction

Construction occupations will experience many changes. Linear measure in the building trades will be in millimetres, centimetres, and metres. New folding rules and tapes will be needed. Since 95 percent of the measurement used in building construction is linear, working familiarity with these units will meet most needs. Area measure will be in square centimetres and square metres. Workers will find that changing from one unit to another within the metric system based on tens, hundreds, and thousands will simplify measurement and computation.

Civil, architectural, and roadway technologists will use kilometres for distance and hectares for land area measures. Volume and capacity measure for earth removal or fill, concrete, and space will be the cubic metre.

Heating, cooling, ventilating, and plumbing specialists will calculate flow rates in litres per second, heat in kilowatts, and measure pressure in kilopascals.

Architectural, engineering and product standards for construction materials will change. The International Standards Organization has adopted a ten centimetre building module (also written as 100 millimetres) which is about four inches. It is planned that sizes of lumber, wood-based panel products, gypsum board, bricks, doors and windows will be manufactured to new dimensions based on ten centimetres or multiples of ten centimetres. Some U.S. industry committees have proposed panel sizes based on this module, with the changeover to be made during 1980-82.

Pipe dimensions may change slightly, while plumbing fixtures are likely to be designed to fit into the spaces created by using the ten centimetres building module.

## Health

Health occupations have become predominantly metric within the past decade as a result of metric conversion of product lines in the U.S. pharmaceutical industry. Changes required for

complete conversion are relatively minor—using degrees Celsius for temperature, using metric scales or modified scales to weigh patients; using equipment in metric units for measuring height and length; recording patient data and dietary information in metric units; and using metric terms in correspondence and communications. Pressure gages will change from psi readings to kilopascals, and oxygen flow rates will be expressed in litres per minute.

Home Economics Related Occupations

In food preparation metric recipes will change to millilitres, grams, litres, and kilograms. Baking pans and molds will be sized by litres and millilitres or by centimetres. However, the same measuring instruments could be used. For all practical purposes, a litre is a little more than a quart; 250 millilitres is a little more than a cup; a teaspoon holds five millilitres; a tablespoon holds fifteen millilitres; and a kilogram is a little more than two pounds—so one-half kilogram will be a little more than one pound. Scales can be relabeled in grams or in dual-reading dials so they can be used for either metric or customary recipes. Baking and cooking temperatures will change to degrees Celsius.

Food management occupations will find that food packaging will change. New standards for food packaging may mean that there will be fewer sizes. Unit pricing and comparison shopping will be easier. Supervisors and workers will need to be able to associate metric units of size and weight, and standard metric packages, with cost and number of servings. Food management supervisors should be prepared to train employees in metric measurement.

Clothing production, dressmaking, and tailoring occupations will find that thread will be marketed by the metre and clothing measurements will be in centimetres. Yard goods will be sold by the metre, and fabric widths may change slightly. Metric patterns and measuring tapes are available.

Child care occupations will find everyday metric units will meet most needs. Body dimensions will be measured in centimetres, weight in grams and kilograms, and body temperature in degrees Celsius.

Hospitality and Recreation

Recreation workers are familiar with some metric measures—the three-metre diving board, skis in centimetres, Olympic races and relays in metres and kilometres, international auto races, and so on. Equipment and clothing sizes, and layouts for sports may change slightly to avoid using complex numbers in metric units. Once employees and employers adjust to the use of metric terms, calculations and comparisons will be easier. Hotel and lodging occupations will describe distances in kilometres and metres, and prepare advertising in metric measures. Purchases and inventory will be in metric units. Alcoholic and non-alcoholic beverages will be marketed in millilitres and litres. Communication with foreign tourists will be easier. Quantity food purchases and preparation will be based on metric units and metric packaging. Cooks, chefs, bakers, and supervisors will need to adjust to the changes.

Institutional Home Management and Supporting Service, including custodial and maintenance workers, will need to prepare solutions in litres and millilitres, some will find pressure gages will change from psi to kilopascals, and degrees Celsius will be used for indoor and outdoor temperatures. All supervisors and managers should be prepared to train their workers. Metric units in everyday use will meet most needs.

## Manufacturing

Manufacturing occupations are being affected early in the metric transition process. While there will be many changes in measuring units and engineering standards, each worker will use only a few specialized units or standards in his or her work.

Machine tool occupations will use millimetres and micrometres for length. Metallurgy, foundry, heat-treating, ceramic, plastic molding, and welding occupations will use degrees Celsius for temperature. The many specialized technical measuring units will be reduced to a few. The many units for energy and horsepower will be replaced by the watt, or kilowatt, and the joule. Pressure and stress can be measured by the pascal, kilopascal, and megapascal. Pressure gages will gradually be replaced or modified.

Most manufacturing and packaging machines can be adjusted or modified for production in metric units or revised standards.

Students will need to work with metric wrenches, and dual-reading or metric vernier calipers and micrometers.

## Marketing and Distribution

Workers in marketing and distribution occupations can play a key part to help the public adjust to metric units and new standards. Those in general merchandise, hardware, building materials, and farm and garden supplies and equipment are likely to be affected first, and they can help their customers translate needs into metric sizes and packages. Most or all workers will need to know that millimetres, centimetres, and metres replace inches, feet, and yards for linear measure. Square centimetres and square metres replace square inches, square feet and square yard for area measure. Kilometre will be used for distance measure, and square metres and hectares for land measure. Grams and kilograms will be used for weighing consumer goods. They will need to know that 500 grams is about a pound, a kilogram is a little more than two pounds, a litre is a little more than a quart, and 250 and 500 millilitres are approximately a cup and a pint. They will need practice in using metric units, and relating metric measurements to quantities of materials. They will need to learn to distinguish between stock which is based on new standards and stock which is not. Apparel and accessories sizes will be in centimetres.

Individuals in industrial marketing and international trade must be prepared to adapt to metric quantities and specifications quickly and easily.

The petroleum industry has initiated a ten-year conversion program to be completed by 1985. The lumber and panel industries may convert between 1980-82, and a hardwood committee has recommended converting to metric sizes along with Canada in 1979.

New standards in packaging will reduce the variety of sizes to be stocked. Unit pricing, price, and materials calculations will be greatly simplified.

## Natural Resources and Environment

Occupations in this cluster are related to industry, agriculture, government, and foreign trade. Environmental, maritime, and fishery occupations are already using some metric measures charts

and cargo lists. Forestry production, processing, harvesting, marketing, and services are likely to be affected between 1976 and 1982 as Canadian forest products go metric.

Students will need to use millimetres, centimetres, metres, and kilometres for length and distance measures; and grams, kilograms, and metric tonnes for weight. New reference tables will become available for estimation of marketable timber, and planting seedlings. Calculations based on land measure will be made in hectares rather than in acres or square miles. Millilitres and litres will replace measures of liquid and gas volumes in calculation of flow rates, pollution standards, and in preparation of solutions. While many product standards will change, fewer technical terms will be required for pressure, stress, and energy, and calculations will be easier.

Personal Services

Occupations in personal services will not be greatly affected, and they are not likely to be affected soon. Pharmaceutical supplies for barbering, cosmetology and mortuary science will be affected but can be taken in stride.

Physical culture and household pet services will use centimetres for measures of body dimensions, grams and kilograms for weight, and kilojoules instead of kilocalories (commonly called calorie).

Special care may be needed in preparing solutions, but metric units in everyday use will meet most needs.

Product Services (Mechanics and Repairers)

Some occupations will be affected sooner than others, and more than others. Agricultural mechanics, power/automotive mechanics, and small engine repair occupations will need metric wrenches, pressure gages, Feeler gages, and reference charts sooner than some occupations. They will use metric micrometers and calipers, and metric-sized taps and drills. Some inch-system taps and drills are the same size as those in metric. Others will need to be purchased to round out the metric set. They will need to identify new kinds and sizes of nuts and bolts. However, a distinctive twelve-spline head has been recommended for bolts with metric standard screwthreads. The millimetre will be used to measure cylinders, crankshafts, and pistons. Pressure will be measured in kilopascals. New reference charts will likely be used with existing testing equipment until it is scheduled for replacement. Business machine maintenance occupations will be affected since the United States both imports and exports a large volume of business machines. Typewriter repairers will frequently be asked to replace keyboard and type symbols with metric symbols. Watchmaking and repair, and appliance repair occupations will not be affected as much.

Public Service and Protective Service

Personnel, training and related occupations, education assistants, and training specialists do not often use direct measurement but they need to use appropriate measurement terms and symbols, recognize when they are used reasonably and correctly, and be able to instruct others in their use. Industry training personnel are among the first to feel the affects of metric conversion.

Child care center and teacher assistants will measure and record personal data in centimetres, and grams and kilograms. Degrees Celsius will be used to measure temperatures, determine proper room temperatures, and dress children appropriately for outdoor temperatures. They will need to know normal body temperatures and be able to react quickly when body temperatures exceed reasonable limits. With changes in consumer products, they will order and inventory consumable supplies in metric quantities and need to relate metric sizes and packages to actual quantities and servings.

Some public service occupations will issue patents, licenses, construction contracts and permits, and deeds in metric measurements. Inspectors will need to use appropriate metric measuring devices, and become familiar with changes in construction, building, and engineering standards. Others will need to become familiar with a variety of metric units, terms, and symbols, and their uses.

Generating plant and stationary energy source occupations will find that electrical energy units will not change, but thermal units will be measured in joules, and pressure in pascals. Equipment replacements or new installations may include these changes. Pumping plants will not change immediately, but eventually flow rates will be calculated in litres per second. Fire and fire safety technology occupations will also be concerned with flow rates, pressure, thermal energy, temperature, and area measure in metric units.

Police science and law enforcement training occupations use a variety of measures for length, volume, weight, and area. Metric units in everyday use will meet most requirements. Special attention should be given to speed and distance estimation and calculation, and recognition of body shapes when metric measurements are given.

Transportation

Automotive technology and services, and diesel mechanics have worked with metric-dimensioned automobiles and engines for some time. Metric tools and equipment are already in place in many school shops, and some metric terms, units, and dimensions are being used. One-fourth of the cars on the road are already metric.

Transportation workers who plan freight loading, make freight and rate calculations, load warehouse materials, and examine lists of cargo will be the first to be affected. Metric units and terms in everyday use will generally meet their needs. They will need practice in using metric units to estimate and measure volume and capacity, weight, length, and distance. Particularly for larger items. Shipping units will be described in litres, kilograms, square metres, and metric tonnes. Size and weight limits for trucks will be given in metres and kilograms. Calculations for loads, fuel consumption, and tariffs will involve different terms which may be difficult to get used to but the mathematics will be easier.

Aircraft load, fuel consumption, and distance terms will change, but it is not clear how soon aircraft mechanics will change.

## Implications for Vocational-Technical Education

While most of business and industry is either in the planning stage or in a "wait-and-see" mode concerning metrication, it is obvious that as of early 1975 the impetus to metricate nationally gained

enormous momentum. A large number of businesses have assigned metric coordinators to the tasks of collecting metric information, developing metric resources in-house, forming committees to study in-house implications of metric, developing policies, plans and time-tables for metricating, developing awareness and education programs for personnel, and designing metric standards for products. Federal legislation would give the necessary sanction for more immediate, nationwide conversion probably phased over a ten-year period. Without legislation, the event will still occur, perhaps more slowly and more haphazardly.

Students emerging from vocational education programs with job-entry skills will be entering a market that is either partially metricated, about to metricate or planning to metricate in the near future. The demand for personnel who understand and can use metric terms, tools, and machines will be increasing fairly rapidly. Even now, knowledge of metric is a requirement for some jobs such as pharmacy technicians, in some parts of the country.

Even though engineering and design standards may not have been determined, those students who are up-to-date on metrication within their own program areas will have a competitive edge in the labor market. It is probable that such students will have more mobility within organizations and businesses since they will have the skills for providing leadership when the time comes. They will probably be depended on to help retrain other employees, will be looked to for ideas and suggestions concerning metric implementation, and may even be asked to provide help with design considerations. The metric changeover will provide impetus for an emerging need where those people with the skills will be in high demand. Vocational-technical programs are in the unique position of being able to provide those skills in a wide range of employment areas and can impact on every segment of our national economy.

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## CHAPTER IV

## METRIC MEASUREMENT AND THE ABE CURRICULUM

### Overview

Adult basic education (ABE) learners come back to school motivated by critical survival needs in their personal lives. Learning the metric system will be meaningful only in the context of these critical survival needs. Until ABE learners see the need to learn metric we can expect resistance.

Preparation of ABE learners for the changeover to the metric system must be in terms of the impact on their daily lives. To make learning meaningful, ABE students should learn only what they need to know to function as consumers or employees.

Due to the diversity of skills and background in the typical ABE classroom, the ABE teacher needs materials which provide for independent study. There must be a sufficient number of concrete exercises that draw on the everyday experiences of the students. The metric materials must be geared to the reading and computational skills of levels I, II, and III.

### Concerns of ABE Personnel

ABE personnel have serious concerns about adding metric measurement to the ABE learning program. Some of these concerns are answered in this section.

Why should my students learn metric when they're so busy coping with what they need to know?

The United States is going metric and the impact will be felt by everyone. To function effectively at home, on the job, in the stores, and on the road, a knowledge of the metric language will be needed to just get along. It is essential to make students aware of this change and prepare them to deal with it.

This also is an opportunity to relearn useful measurement skills, such as reading dials and scales, learning to estimate, and learning to develop a sense of reasonableness for their answers.

I know so little about the metric system, how can I teach it?

The metric system is a small body of information, some of which is already familiar. There are less than fifteen new terms to learn for everyday use. The same materials can be used by teachers to teach themselves first, or teachers can learn right along with the students. As soon as you try it, your concerns will disappear. You will see how easy it is and how little time it takes to learn.

My students have so much trouble with multiplication and division, how can they possibly memorize conversion factors and use them?

Every effort should be made to avoid memorizing and using conversion factors between our present measurement system (foot-pound) and the metric system (metre-kilogram). The only meaningful way to learn metric is to "think metric" and use it exclusively in measurement. In those cases where equivalents are needed, conversion tables are easily available for reference. Using conversion factors will only create more negative attitudes and reduce the efficiency of learning.

We have so little funding how can we possibly buy metric tools and materials?

Few materials will be needed. It would be helpful to have a metric ruler, a metric tape-measure, a metric scale, a Celsius thermometer, and a metric measuring cup. Many of these devices can be made right in the classroom with readily available materials. The metric laboratory can consist almost entirely of inexpensive, home-made devices. If you choose to build your own metric instruments you will have acquired almost all the learning needed to understand, internalize, and use metric measurement. Costly devices and resources may be nice to have but are not necessary to learn metric.

I have so much to teach now, what do I leave out if I introduce metric?

When the metric system becomes the primary measurement system in the United States, students will no longer need to spend time learning difficult computations with fractions. More time will be available for learning other skills. Instructional packages for ABE will be compatible with existing mathematics programs for ABE learners and could replace the measurement units now being taught.

The students in my class are so different, how can I possibly meet their individual needs?

You will teach some of the materials to all of the students, all of the materials to some of the students, but not all of the materials to all of the students. The units are based around a single concept such as linear measurement, area measurement, mass measurement and the like. The teacher can devise a program by choosing only those units which meet individual needs. The units should be written for different reading and computational skills levels to match ABE levels I, II, and III.

## Characteristics of ABE Learners

Certain characteristics distinguish ABE learners. These motivational, psychological and cognitive, and social and economic factors all have implications for the program that should and can be conducted.

### Motivational Characteristics

When people are drowning they don't want to learn a second language. They just want to be able to yell "help" in their native tongue. Adult basic education learners focus on acquiring skills, information and understandings which relate directly to the emotional and survival pressures in their personal lives. For example, some people enter ABE programs because new job opportunities are

available, or additional math and reading skills are needed to keep the same job. Some entrants are women without job skills who find they suddenly must support themselves and their children. In other cases, persons enter the program because their school-age children have asked for help or have asked questions that the parents cannot answer.

Given these personal pressures to perform, ABE learners want to acquire new skills quickly and tend to underestimate the time or energy required. These learners may not distinguish between short-term and long-term outcomes and tend to underestimate the number of steps needed to reach goals. Understanding requires planful behavior which is not characteristic of ABE students. Learners' beliefs conceming previous experience with school usually define their success or failure with a new school experience. This suggests that teachers and counselors should work with students to redefine the notion of school and learning. They should alter the nature of the learning environment by spelling out the steps and expected outcomes of a learning experience.

People with low self-esteem tend to fail when they set difficult goals for themselves. Persons with a history of failure tend to aim for outcomes in ways which multiply their chances of failing again. Despite this background of failure in the school setting, ABE learners are voluntary students. This is rather remarkable. Something has led these students to hope for different outcomes this time. There is a willingness to try and a seriousness of purpose which sets these students apart from high school students.

These students want to learn! It is what, how and when they want to learn that creates problems.

### Physiological and Cognitive Characteristics

The ABE population consists heavily of older adults even though there is a growing shift to a younger target group. Older adults tend to have shorter attention spans, decreased hearing ranges, and do not see as well as younger persons. Older adults are less likely to perceive, look for or recognize new uses for a familiar object. The immediate consequence of these characteristics is that problem-solving behavior tends to become fixed since it is based on past experience which "sets" perceptions about the nature of others and of things. It also correlates with findings that dogmatism relates positively to age and negatively to education. This raises questions about ABE learners' ability to adapt spontaneously and positively to new kinds of materials, content, and instructional technologies without help from teachers, guidance personnel and administrators (Bortner, 1974).

### Social and Economic Characteristics

ABE students often have families to support and jobs to maintain. These learners can only assign part of their time and energies to learning. They often earn very little money and tend to live in a state of crisis which affects their ability to learn and perform. A typical ABE classroom will contain a wide variety of ages, jobs, experiences, needs, desires to learn and study, and expectations among its students. It is a very diverse classroom.

## Implications of ABE Learner Characteristics for Metric Education

ABE learners are voluntary students whose immediate needs require that anything learned be immediately relevant to their real world. This requirement is essential. If it is violated students will

quit. Learning to use metric measurement will become a critical need when the stores, kitchens, repair shops and highway signs use metric measurement. Since this is going to happen soon, we must prepare the student for this change. We must make learners aware of the coming metric changeover and help them understand how it will impact on every aspect of their lives. This can be achieved by using realistic examples drawn from the learners' everyday experiences.

Materials must be designed which give learners opportunities to practice. The materials must permit the teacher to provide independent study. To meet the needs of ABE learners, the materials should consist of single concept presentations and exercises which relate directly to the everyday lives of the students and to their job aspirations.

## Scope and Sequence of the ABE Metric Measurement Program

With the United States moving toward adoption of the International Metric System, everyone will be faced with the task of learning a new measurement language. The learning of this new language will have an additional implication for ABE students in that it will provide them with a second chance to learn basic measurement skills.

A major guiding factor in selecting metric content will be the practicality of the information and its usability by ABE students. Every effort should be made to include those metric terms that most people will encounter in their day-to-day activities or will need for basic job-entry level. Technical terms and definitions and rarely-used units should be avoided.

The sequencing of the metric content should be guided by the mathematics programs presently used in ABE learning centers. Every effort should be made to make the metric content compatible with existing programs.

### Scope

Special attention will be given to the development of language units. Everyone should be capable of recognizing and using appropriate metric terms and symbols in their everyday reading, writing, and speaking. An "appropriate" unit is one which is "correct in type" and "reasonable in size." Consideration should be given to integrating into the ABE curriculum the list of terms, prefixes, and symbols found in Tables 1 through 4 in Chapter I. The proper use of decimal notation, as in 2 500 000 kg and 0.5 cm also should be included.

The metric terms and symbols cannot be internalized unless reinforced through active use. Students will learn by making measurements in the units as they are introduced. Students should build personal reference systems before working mathematically in the system. Students should acquire several measurement skills, including the following:

1. The ability to state or identify the approximate magnitude of the metric standards for length, capacity, mass, and temperature (including their multiples, submultiples, and derived standards).

2. The ability to state readings from the scales of various measuring devices to their intended degree of precision.

3. The ability to make reasonable, "common sense" estimates for a measure.

4. The ability to measure quantities and to check the appropriateness of the measures with estimates.

5. The ability to state a given measure using different units; e.g., 1.5 m or 150 cm.

6. The ability to state relationships between certain measures as in one gallon of water weighs eight pounds or one litre of water has a mass of one kilogram.

Once such skills are acquired, students should learn to make indirect measures and comparisons. Students should work mathematically with the metric units and numbers to obtain skills similar to those below.

1. The ability to convert a measure in one unit, or a combination of units, to an equivalent measure in another unit of like quantity (intra-system conversions).

2. The ability to compare numbers resulting from measures of a given quantity.

3. The ability to perform fundamental operations with numbers and units resulting from measures.

4. The ability to compute indirect measures by using appropriate direct measures and computational formulas including consideration of perimeter, area, and volume concepts.

To ensure that transfer from the mathematical and measurement skills to practical applications takes place, students will have opportunities to use metric measurements and referents. Throughout students' experiences with metric concepts, applications should be presented in the areas of consumer economics, transportation, health, community resources, government and law, and occupational knowledge.

Sequence

In determining how these experiences could be sequenced to be understandable and meaningful to ABE students, computation skills, reading level, work experience, and immediate needs of the students should be considered. Based upon these and other criteria, the content list for the first three levels of an ABE program was compiled and listed in Table 5. An "x" is used to indicate the level(s) at which each term will be included in the metric program. It is important to remember that not all students will need to cover all of the material at a given level. The content that is relevant to each individual depends upon personal needs and goals.

Curriculum based upon this content will provide students with a sequence of experiences in recognizing relationships between units; reading scales of the units, using the appropriate symbols and decimal notations associated with the units; recognizing when the units are appropriate to use; and using the units in several everyday and job-related measurement situations.

Table 5

METRIC CONTENT BY ABE LEVEL

| Unit \ Level | I | II | III |
|---|---|---|---|
| s (second) | x | x | x |
| m (metre) | x | x | x |
| km (kilometre) | x | x | x |
| cm (centimetre) | x | x | x |
| mm (millimetre) | | x | x |
| kg (kilogram) | x | x | x |
| t (tonne) | | x | x |
| g (gram) | x | x | x |
| ℓ (litre) | x | x | x |
| mℓ (millilitre) | x | x | x |
| ha (hectare) | | x | x |
| $m^2$ (square metre) | | x | x |
| $cm^2$ (square centimetre) | | x | x |
| $m^3$ (cubic metre) | | x | x |
| $cm^3$ (cubic centimetre) | | x | x |
| km/h (kilometre per hour) | x | x | x |
| Pa (pascal) | | | x |
| kPa (kilopascal) | | | x |
| A (ampere) | | | x |
| J (joule) | | | x |
| kJ (kilojoule) | | | x |
| W (watt) | | | x |
| kW (kilowatt) | | | x |
| °C (degree Celsius) | x | x | x |

The content for Level I students should be at low reading and computational levels. The overall purpose of the experiences will be to acquaint the students with the most commonly used metric units and measuring devices and to teach them their appropriate uses. The work at this level will also focus upon allowing students to build personal metric references based upon their own individual needs and experiences.

The content for Level II students should be at a fourth grade reading level and involve computation with decimal numbers. In addition to a review of the material covered at Level I, indirect measures should be introduced. Job-entry level requirements should be considered in the applications.

For Level III students, materials should be at a sixth grade reading and computational level. In addition to reviewing topics covered at the first two levels, Level III materials should stress the logical structure of the metric system and include special units not previously considered but relevant to consumerism and occupational knowledge.

Throughout the instructional materials, the needs of the students should be the major factors in determining the content, method of presentation, and type of applications included in the program. This should result in a metric program that is educationally sound, technically correct, relevant, and motivating.

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## CHAPTER V

## CURRICULUM AND INSTRUCTIONAL STRATEGIES

### Overview

Appropriate metric content can be identified by looking at worker performance tasks which use measurement, measurement tools, and measurement terms and symbols. However, everybody also needs to learn commonly used metric units, develop a "feel" for the sizes of the units, and have a positive attitude toward themselves and their ability to learn and use metric measurement.

The pacing of curriculum change should match changes in business, industry, and society. As metric transition proceeds, and metric engineering product standards are developed and adopted, the curriculum must be changed to include this new information.

Metric instructional planning should include obtaining occupationally-related self-study materials, keeping metric content simple and useful, a "think metric" approach, developing positive attitudes toward mathematics and improving decimal notation and measurement skills.

The "think metric" approach is the only effective way people can learn to use the metric units required on the job, in the marketplace, and in the home. Students need many experiences in estimating and verifying the metric sizes of physical objects to develop the ability to "think metric." Familiarity with the basic metric units and their uses will reduce errors in mathematics and on the job.

### Concerns of Teachers and Administrators

Questions that teachers and administrators have about the metric curriculum are answered in the following section.

#### What are the characteristics of good metric instructional materials?

Good metric instructional materials for vocational and technical education will be based upon analysis of the measurement tasks workers perform in their jobs. The instructional program will provide content and practice appropriate to the work situations that students will encounter later. Learning activities, exercises, and test items will emphasize the needs of the job. For ABE programs, instructional materials will emphasize this same realism, but be based upon ABE students' needs as consumers, family members, workers, and citizens.

Instructional materials should avoid conversion from customary to metric or vice-versa and should be concrete. They should be relatively inexpensive, easily reproduced, and have minimal

hardware requirements so that schools can afford them and students can use them outside the classroom.

Instructional materials should be suitable for use by the whole class, or by individuals or smaller groups. Test items for sections and for the entire instructional package should be provided. Written materials should be kept to a minimum and be easy to read. Suggested learning activities and projects should be relevant to the job requirements and contribute to the achievement of the desired learning outcomes.

How do I decide what metric content to teach first, second, and so on?

Students must learn to think in metric units before they make mathematical computations, take highly precise measurements, or use precision measurement tools. They should receive a little information about a metric unit, estimate the metric measurement of familiar objects or quantities, and verify their estimates by taking measurements. Students should be given practice and feedback so that they can improve their "feel" for the size of the unit and its use. Begin with the metre, the centimetre, and the millimetre, which are basic units. Then progress through a logical sequence: linear measurement units, area measure, cubic measure, volume measure, and temperature measure. Addition, subtraction, multiplication, division, and the use of whole numbers and decimal fractions will usually be all that is needed for using metric units. Following informal estimation experiences, basic metric units and derived units can be related to common work and life tasks. Here, the order of presentation may be based on how often the worker uses the measurement unit, and when the measurement content is usually learned in courses.

How can I reduce student anxiety about learning metric measurement?

Anxiety can interfere with learning. Informal activities should be used at first to reduce anxiety concerning metric measurement. These activities should allow wider acceptable margins of error and encourage student self-checking.

Anxiety about a learning task can be reduced by distributing the amount of content and the learning activities over time. In the beginning, students should not be shown all of the metric units to be learned. Extensive charts with scientific definitions should not be used. They may verify the students' fears that the metric system is difficult to learn. As soon as it is practical, students should use metric units in projects and activities.

Learners need an appropriate level of challenge—not too hard and not too easy. Content should be organized in sections that present different levels of challenge and students should be able to take brief pre-tests to find the appropriate point to begin.

Students should have a pleasant, successful experience in their initial exposure to metric content—to overcome frustrating math experiences in the past, relieve fears and concerns, and establish a positive view toward the use of metric measurement in the future. This should be of major concern in planning curriculum and instruction. Metrics should be presented in the context of students' needs, interests, experiences, and expectations.

Learning experiences should be as similar to the performance situation as is practical. If the student will be using metric tools or dual-reading equipment, using look-up tables, filling order

blanks, or proofing typed copy on the job, these learning activities should be included in the instructional program. Instructors should avoid the temptation to teach the students all there is to know about the metric system.

As an administrator, how do I decide which occupational areas to metricate first?

The pacing of curriculum change in the schools should be consistent with the change in related businesses and industry. The following factors should be considered: (1) Are metric measurement skills necessary to perform tasks? (2) To what extent have domestic producers and suppliers made the metric transition? (3) How soon will the students need to use the metric system? (4) Can the curriculum changes and the materials prepared be used to spin off changes in other occupational areas? For example, agricultural farm operations, forestry, and horticulture will have changes in common. Some materials prepared for one area can be adapted for the others.

The first to feel the effects of the metric changeover will be those occupational areas which produce measurement-sensitive products for export, such as the off-road vehicle industry and those which use imported measurement-sensitive products.

Related occupations in engineering design, production design, drafting, casting, and machining are already being affected. Business and office occupations which relate to ordering, billing, shipping, and communicating about these products are affected. This includes bookkeepers, stenographers, clerk typists, receptionists, and information clerks. Industrial salesmen and related suppliers, vendors and instrument firms are affected. Pharmaceutical and health occupations workers, including hospital food service workers, may need early assistance. Much of the industry and public changeover will occur between 1975 and 1985. Personal services occupations may be among the last to feel the major effects.

What types of learning are involved?

The principal type of learning is discrimination among metric units, terms, and symbols. Students need mental images and physical senses for the units they will use in job tasks. This is the "think metric" strategy. Students will need to be able to recall metric units, terms, and symbols—remembering what they are; how they are written, spelled, and pronounced; and when they are used. Students will need skill in decision making—recognizing when measurement is required, what type of measurement should be used, what level of precision is appropriate, what tool is used, how to use it, how to convert the results to the most useful form, and how to record or apply the results. Students will need to learn new manipulative skills if they have not already mastered the use of measuring instruments. Basically, there is no difference between using instruments to measure in metric units and measuring in customary units.

## Curriculum Strategies

The following suggests techniques to use in identifying and selecting metric content and sources of appropriate content.

## Content Identification and Selection

In identifying metric content, it is well to keep in mind that only the language of measurement, the sizes of the units, some tools, and some product specifications are changing.

Teachers, administrators, and curriculum developers must determine what students need to know about metric, what they need to be able to do, when they need to be able to do it, what feelings about it would be most helpful, and how it can be organized and experienced so that learning can be easy, enjoyable, and meaningful.

Content should be selected and included only if it is useful to the teacher or student now or in the near future, is necessary for the student to be able to perform essential tasks, is available to be learned, can reasonably be learned by the student, or helps the student understand and use the metric system.

To be useful and necessary whatever is selected for learning must have some practical use in "the present or anticipated life situation of the learner" (Johnson, 1967). Foreign and domestic experiences in metrication indicate that learning experiences should not occur too far in advance of application. Metric education should be held to a minimum, that which is absolutely required for the user to perform essential functions or tasks (U.S. Metric Study; Education, 1971; Chalupsky and others, 1974).

Metric system content should be as streamlined and simple as is possible and practical. Some instructional materials stress or give equal treatment to the prefixes deci- (tens) and deka- (tenths) as used in decilitre and dekalitre, decigram and dekagram, and decimetre and dekametre while others do not. These measurement intervals can be used to help explain the logical relationships among volume, mass and length; however, they are not likely to be used as regular measures in occupations or consumer situations. In the interest of simplicity, we recommend they not be taught as regular measurement units.

Some metric education information which students will eventually need to learn is not yet available. National and international organizations are continuing to develop and adopt product standards. The lack of accepted metric engineering standards in many fields will affect the selection and treatment of some vocational occupational areas. When the standards are developed, the curriculum can reflect the change.

Metric education concepts, content, processes, illustrations, and applications can be identified and selected by considering these major elements:

1. Home and community tasks involving measurement.
2. Business and industry tasks involving measurement.
3. SI metric system standards and practices.
4. Engineering standards and practices.

5. Mathematics - logical sequencing of learning, mathematics operations, decimal notation, rounding numbers, estimation.

6. Measurement concepts, tools, and processes.

7. Learner characteristics, experiences, and expectations.

8. School organization, curriculum, practices, and facilities.

9. Resources - time, money, materials, equipment, and human resources.

Sources of Content

Sources of information on SI metric standards and practices are:

"The International System of Units (SI)," NBS Special Publication 330 (1974), Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

"ISO Standard 1000, SI Units and Recommendations for the Use of Their Multiple and of Certain Other Units," (1973), American National Standards Institute (ANSI), 1430 Broadway, New York, New York 10018.

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"Metric Editorial Guide," (1974), American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

"ASTM Standard E380, Metric Practice Guide," (1972), American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Sources of information on engineering standards are the regular and special publications of professional associations, technical societies, standards organizations, and government agencies.

## Instructional Strategies

Metric instruction will be more effective if a "think metric" approach is taken, positive attitudes about mathematics are fostered, deficiencies in measurement skills are remedied, concepts are internalized, and outcomes are emphasized.

### The "Think Metric" Approach

Thinking in metric terms is essential for a successful changeover to the metric system. Research findings in the United States (Reese and Cathcart, 1974), and in foreign countries (Chalupsky and others, 1973) has shown that when measurements are available in both customary and metric units,

individuals rely on the familiar units and do not use or remember the metric units. Mathematical conversion between metric and customary units creates confusion and uncertainty in the use of metric measurement and does not lead to learning metric units.

The values of metric units need to be firmly associated with physical quantities which are familiar to students. These associations can be made with physical objects in the environment, with mental images or concepts over which the student has good command, or with physical senses which the student has developed. A student who associates one millimetre with the thickness of a standard paper clip wire is not likely to forget it. Repeated practice in estimation, verification is necessary to develop and refine the ability to think in metric units.

One problem in metric education curriculum change will be that some instructors will insist "we are already teaching metric measurement." However, many are teaching conversion formulas only. The students should not need to make a mathematical conversion to determine:

1. whether to wear a coat on a 25 °C day,
2. how large or how small a 250 millilitre solution is,
3. how long a 1200 millimetre board is,
4. how thick a 1 millimetre wire is, or
5. how high a body temperature of 38 °C is.

Students in occupational program areas and in adult basic education programs must be able to think in those metric units which will serve them well in work and life situations.

The "think metric" approach is the only effective way our citizens can develop ease and facility in using metric units.

## Developing Positive Attitudes Toward Mathematics

Consideration should be given to students' attitudes toward mathematics. Max Bell of the University of Chicago states, ". . . most people willingly confess to incompetence in the use of even quite simple mathematical tools, and their dominant attitudes involve some mixture of awe and distaste." (Bell, 1974).

To improve attitudes and competencies regarding measurement functions, Bell suggests that the schools build in repeated references over the years to a wide variety of measures in everyday experiences and that real world problems be matched with the appropriate mathematical processes, then solved. He stresses the importance of estimation, approximation, verification, and being able to judge the reasonableness of an amount in various situations.

## Overcoming Deficiencies in Measurement Skills

By and large, student deficiencies in mathematics and measurement skills do not result from skills not being taught. The skills are taught but not "caught." There are too few opportunities

to apply the measurement skills in the students' home and school life to be able to internalize and reinforce the concepts or skills, and a very narrow range of skills. It is natural that many are forgotten. Instructional materials must use a "think metric" approach, provide opportunities for repeated estimation and verification, and suggest additional applications.

## Memorizing Metric Content

Some instructors might say their students are "learning" the metric system and metric system units. They say, "Their test scores couldn't be higher." However, there is a difference between memorizing information and internalizing concepts. Memorizing without frequent review and reinforcement leads to forgetting. Internalizing concepts means that the information becomes a part of the mental structure of the individual and is supported by other concepts and logical structures so that it is not easily forgotten. Students will memorize information for tests, and instructors will sometimes teach for tests unless enough stress is placed on conceptual development and applications.

## Undertaking Projects

Vocational-technical education has often been best when teachers and students engage in solving problems in the school and community by applying their knowledge and skills to projects and activities based on real needs. Metric education and metric transition in the school, business and industry, the home, and the community provides new challenges and opportunities for vocational education teachers and students. They can:

1. work together in their shops and labs, and work with other departments to identify measurement tools and devices things which need to be changed in the school, the home, and business and industry;

2. identify tools and equipment which can be used with minor changes or modifications, and plan and make modifications;

3. design, and produce or supply materials, services, and communications to assist in metric changeover at school and in the home, business and industry, and the community;

4. develop new ways to cooperate among school programs, business and industry, the home, and the community;

5. develop a sense of partnership with adults, professionals, and children as they all learn to use a new measurement system;

6. develop greater self-confidence as they make changes which help other departments in the school go metric.

## Relating Instruction to Job Requirements

Planning instruction for metric education by focusing on occupational tasks and performance outcomes can help:

1. Relate metric content to appropriate occupational roles.

2. Eliminate unnecessary metric content; e.g., content relating to the history and development of the metric system, which does not relate to performance.

3. Identify the frequency of task performance and the difficulty of the learning task so instructional time and resources can be used wisely.

4. Identify the type of learning to be achieved so that learning can be matched with performance needs, e.g., to develop skills in typing copy containing metric terms.

5. Provide a framework for preparing self-study learning materials so that individuals or small groups can begin metric education at convenient times and progress at their own rate.

6. Let the learner know what is to be learned and the conditions under which he may be expected to perform.

7. Suggest methods for selecting and sequencing performance objectives, content, and learning tasks.

8. Provide measurable outcomes for evaluation of materials and student experiences, so that learning experiences and materials can be revised and improved.

Vocational and technical education students often work at training stations as individuals or in small groups. The instructor circulates from individual to individual or from group to group. Adult basic education students enter and leave the program at various times and they want to make progress at their own rate. Given these conditions, metric education materials should be self-instructional and provide the student with feedback. The instructor could still use the materials with small groups or with the whole class.

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